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# UNPUBLISHED PRELIMINARY DATA

13 January 1965

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Copy No. 18

Report for Contract Nonr-3579(04)  
for the period 1 September 1964 through 30 November 1964

Supported by Fund Transfer R-129 from Office of Grants and Research Contracts,  
National Aeronautics and Space Administration

by

Lloyd A. Jeffress

378.

During the second quarter of the contract period the following has  
been accomplished.

N 65 16816

Code-1 Cat-85

NASA CR-60441

## I. Instrumentation

Programming equipment for all of the proposed studies is now complete and installed in Mezes Hall, The University of Texas. Because of the effectiveness of the rating-scale device, a second model has been constructed so that two subjects can furnish ratings and two subjects, yes-no responses to the same stimuli at the same time.

The physiological recording equipment has just been received after several months of delay at DIPEC. Permission to buy a much needed dual-beam oscilloscope for which application was made in June, 1964, has not as yet been received from DIPEC.

## II. Proposed Problems: Status of

### A. Problem 1. Receiver Operating Characteristics for Visual Detection

Work on this problem is underway. The stimulus being employed at present is a simulated A-scan on an oscilloscope. Both the noise and the signal appear as vertical deflections of the scan. The noise is continuous across the scan, and the signal, which is either present or absent, occupies a space near the center of the scan. The subjects' task is to indicate by means of the rating-scale device their degree of certainty that a signal was present during the scan. After this elementary study has been completed, other visual stimuli will be employed.

B. Problem 2. Signal Detection as a Function of Vigilance

Work on one aspect of this problem has been completed. The results are summarized in Appendix D, which is the text of a paper presented at the October meeting of the Acoustical Society of America. Work on the problem will be continued with recordings made of appropriate autonomic functions. The equipment for such recording has just been received.

C. Problem 3. Signal Duration and the Width of Critical Bands

Work on this problem is being deferred to await the outcome of another closely related experiment.

D. Problem 4. Detectability of Minimal Signal in the Absence of External Noise

This work is underway but the results are not sufficiently numerous for a summarization at this time.

E. Problem 5. Detection by Multiple Observers

Data for this problem are being gathered concurrently with other experiments. Since in many of the problems four subjects are run at a time, data on two, three, or four observers can be gathered simultaneously with data for the basic experiment. Results so far appear to indicate that there is consistently better detection as the number of observers is increased.

F. Problem 6. Detection and Response Latency

This is a new problem which grew out of other work. It is essentially a choice-reaction experiment in a detection setting. The subject is required to respond "yes" or "no" by pressing the appropriate key as quickly as possible, according as he believes that a signal was present or absent during the signal interval which is indicated by a light. The subjects can be moved along a kind of ROC curve according to their instructions--to react as quickly as possible,

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to react quickly but to be as correct in their responses as possible, to react as quickly as they can without too many errors (Lax, Strict, and Medium criteria). The subjects proved to be able to approach simple reaction time in their speed of response while still performing better than chance in the choice situation. These findings are being prepared for publication and reprints will be issued as a DRL Acoustical Report under the contract.

G. Other Problems

Appendixes A, B, and C are the texts of papers given at the October 1964 meeting of the Acoustical Society of America. The work was begun under BuShips Contract NObsr-72627, but part of the continuation was supported by the present contract and acknowledgment is given to both sources of support.

## APPENDIX A

### Effect of Phase Difference Between Signal and Masker on the Detection of a Narrow-Band Noise Signal

Mark E. Rilling and Lloyd A. Jeffress

In a comparison of tonal and narrow-band noise signals reported by the authors at the May 1964 meeting of the Acoustical Society of America, the masking level differences (MLDs) for the two types of signals proved to be the same for corresponding interaural phase conditions. The work involved using as signals a 500 cps tone or a 50 cps band of noise centered at 500 cps. The masker was a wide band of noise 100 to 3000 cps at a spectral level of 48 dB.

Earlier, Hirsh and Webster had reported that the MLD for a narrow-band noise signal was 22 dB, where as the MLD for a tonal signal was 15 dB--a 7 dB difference. They worked with signals centered at 250 cps where the MLDs are considerably larger than they are for 500 cps, but their large difference where we found none cannot be explained solely in terms of the difference of frequency employed in the two sets of experiments. At the time of the May meeting, we suggested that the difference might have resulted from the fact that we had employed two noise generators, one for the masker and one for the signal, where as Hirsh and Webster appeared to have employed a single generator for both. Later we learned that this was indeed the case.

The present experiment was undertaken to determine whether the results obtained by Hirsh and Webster could be replicated by employing a single noise generator. Theory suggests that there should be an optimal relation between the phase of the masker (within the critical band) and the signal--that the MLDs should be smallest when the two are in phase. Accordingly a phase shifter was introduced in the circuit so that the phase relation between the 500 cps region in the noise and the narrow-band signal could be varied. Six phase relations were employed:  $0^\circ$ ,  $60^\circ$ ,  $90^\circ$ ,  $120^\circ$ ,  $150^\circ$ , and  $180^\circ$ . The results are presented in Table I.

Table I			
Signal-Masker Phase Relation	SPL of Signal (50 cps band) for $d' = 1.5$		
	NO SO	NO $S\pi$	MLD
0°	65.4	53.19	11.5
60°	66.6	53.18	12.8
90°	67.0	54.2	12.8
120°	68.9	53.7	15.2
150°	70.7	53.5	17.2
180°	72.2	54.2	18.0

It will be seen that the smallest MLD does occur when the masker and signal are in phase. The largest, 18 dB agrees well with the Hirsh and Webster finding of 22 dB when the difference of frequency is taken into account. Apparently their equipment had introduced a phase reversal in the signal channel.

The results presented at the May 1964 meeting showed a 14.8 dB MLD for the narrow-band noise signal where an independent noise-source was used for the signal. This value is about midway in the present series.

Examination of the table reveals a surprising fact, that the signal required for detection ( $d' = 1.5$ ) remains about constant throughout for the NO  $S\pi$  interaural phase condition. It is the signal required for NO SO that varies to produce the varying MLDs--progressively stronger signals are required as the phase relation between signal and masker is varied from 0°. This fact makes sense if we remember that where the phase relation is 0°, we are adding the signal energy to the noise energy, and that when it is 180° we are subtracting. It therefore takes a stronger signal for detection when the phase is 180°. The phase shift created by the narrow-band filter, in one direction for frequencies above the center frequency (500 cps) and in the opposite direction below, is responsible for the fact that the subtraction is not perfect. Measurement shows it to be about 6 dB for the stimuli employed.

The constancy of the signal levels needed for constant detection ( $d' = 1.5$ ) under the NO  $S\pi$  condition is also owing to the phase shifts introduced by the filter. The interaural phase shifts resulting extend over 90° and so present to the ears almost the same pairs of stimuli whatever the setting of the phase shifter.

## APPENDIX B

### Receiver Operating Characteristics by Rating Scale for Antiphasic Stimulation

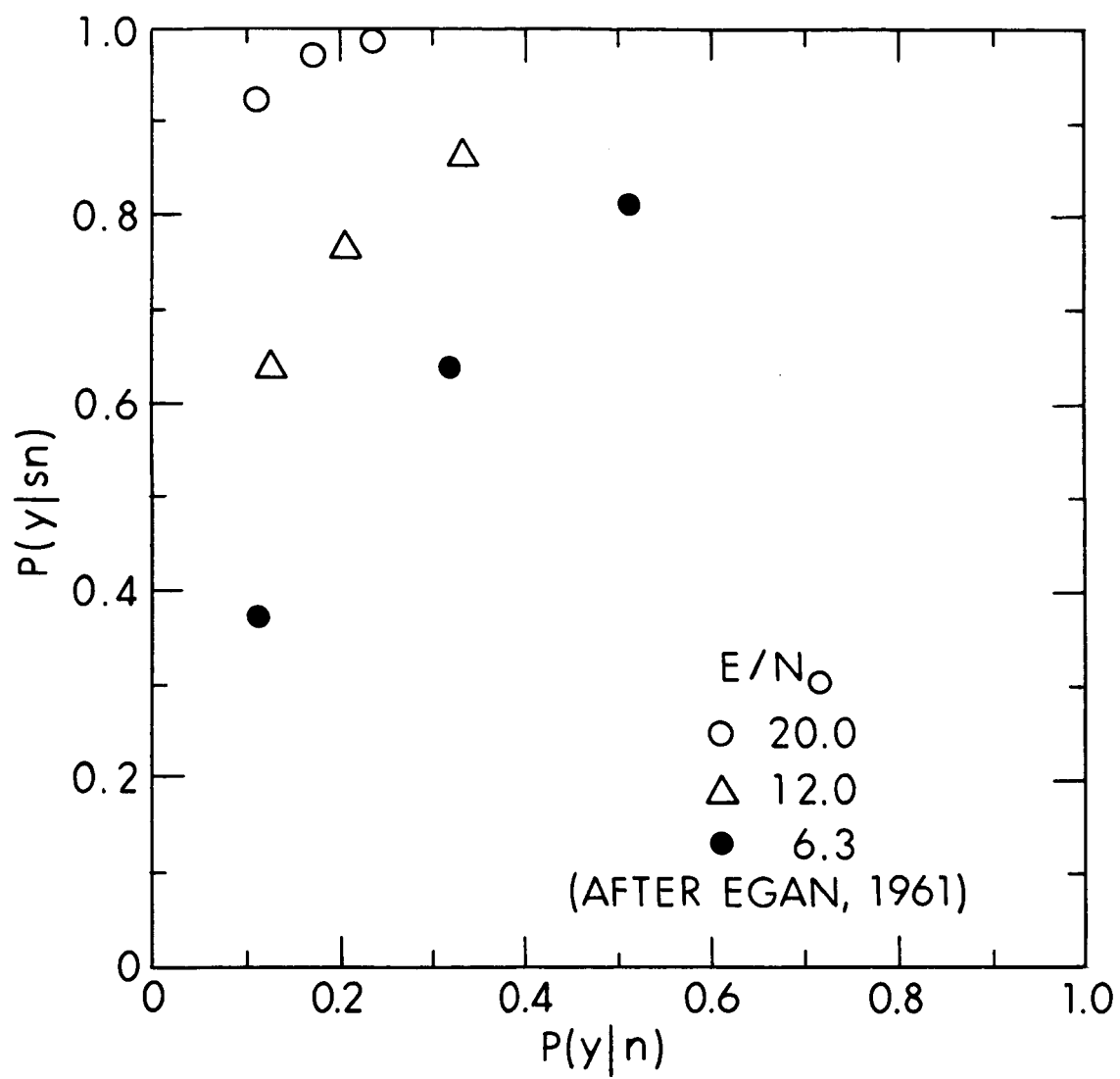
Charles S. Watson, Mark E. Rilling, and Walter T. Bourbon

The first method of determining the shape of the receiver operating characteristic (ROC) in auditory detection was to ask the listener to adopt a different criterion of acceptance in each block of trials, strict in some blocks, lax in others, and medium in still others. Egan (1959) showed that subjects could produce the same functions by using rating scales, responding "one" when they were certain that a signal had been presented, "two" when less certain, and so on. The rating scale procedure reduced variability and yielded several points on an ROC curve from a single listening session.

An example of Egan's rating scale results is seen in Dwg. AS-10080. We have removed the normal-distribution-based theoretical curves which Egan had fitted to the points. Results like these made it difficult to determine the exact shape of the ROC curve, except that it does not resemble the most naive of threshold models, the correction-for-guessing model, which predicts some detection outside the bounds that limit even the theoretical ideal observer. The general shape of the curves that might be passed through these points is quite like that which would be generated by overlapping, normal, equal-variance distributions of noise and signal plus noise, as may be seen in Egan's original figure.

Egan (1959) and Pollack and Decker (1958) have suggested that the subject can make a fine-grained decision based on each input. The present authors believe that, just as sensory input is graded, so should optimum responses be graded for maximum information transmission. Such would be the case, but for Miller's "Magic Number 7" (1956), the apparent limit on the number of response categories that an observer can use effectively. The present authors thought it possible that this limit is a function, not of the coarseness of the information carried through the system, but of difficulty in terminal response encoding.

In an earlier study, Watson, Rilling, and Bourbon (1964) made use of a device designed to make graded responding as easy a task as possible. The device consisted of a box with a 14-inch slot along the top. A slider could be moved back and forth in the slot and a pointer, out of the subject's view, indicated the exact position of the slider. The experimenter read the pointer setting, which constituted a response, after each trial.



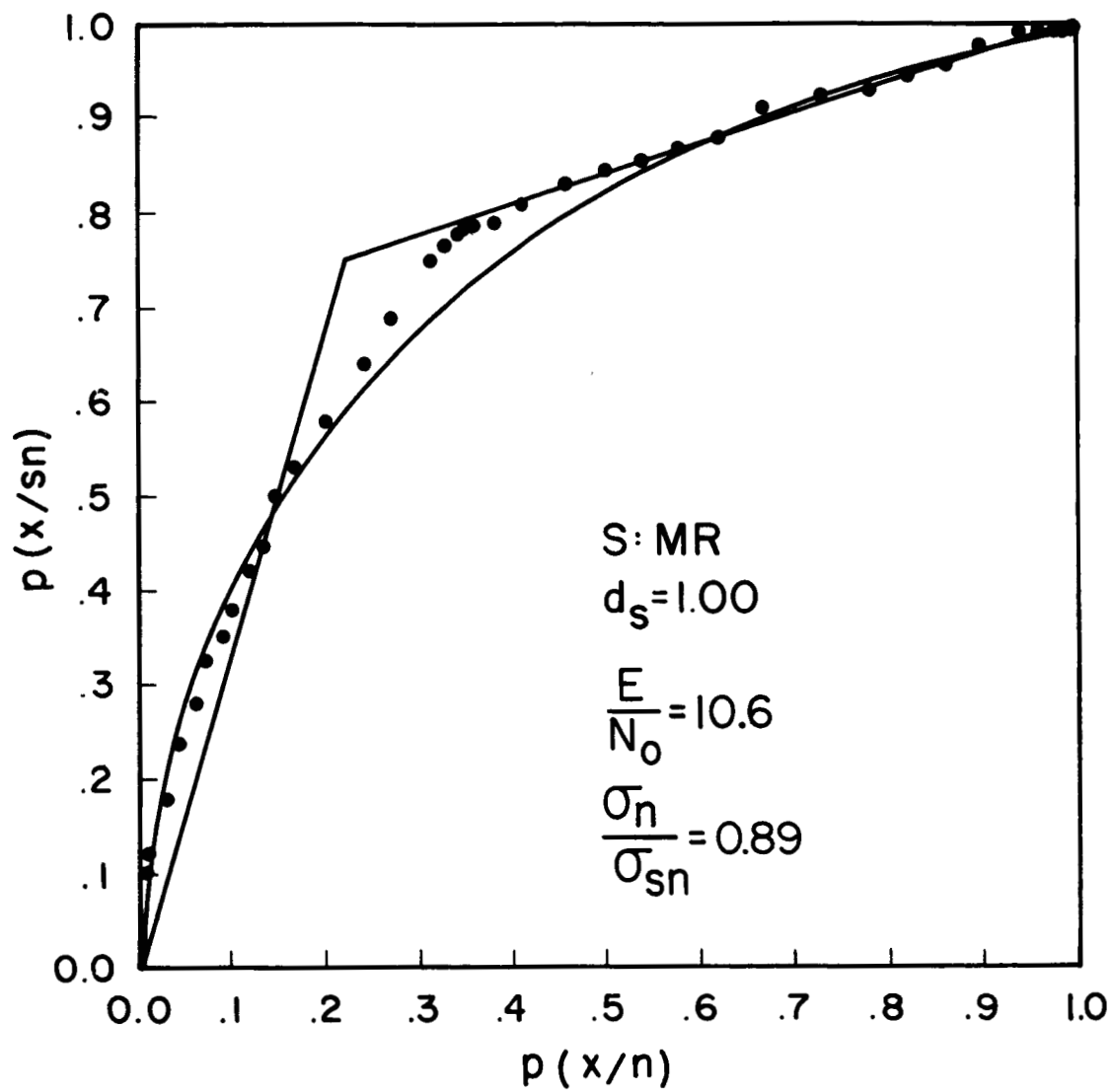
Subjects were trained in a typical, single-interval, masking experiment and were told to position the slider all the way to the right if they were certain that the signal was presented, all the way to the left for similar certainty that no signal was presented, and to use positions closer to the center when less certain. The center itself was marked and represented maximal uncertainty.

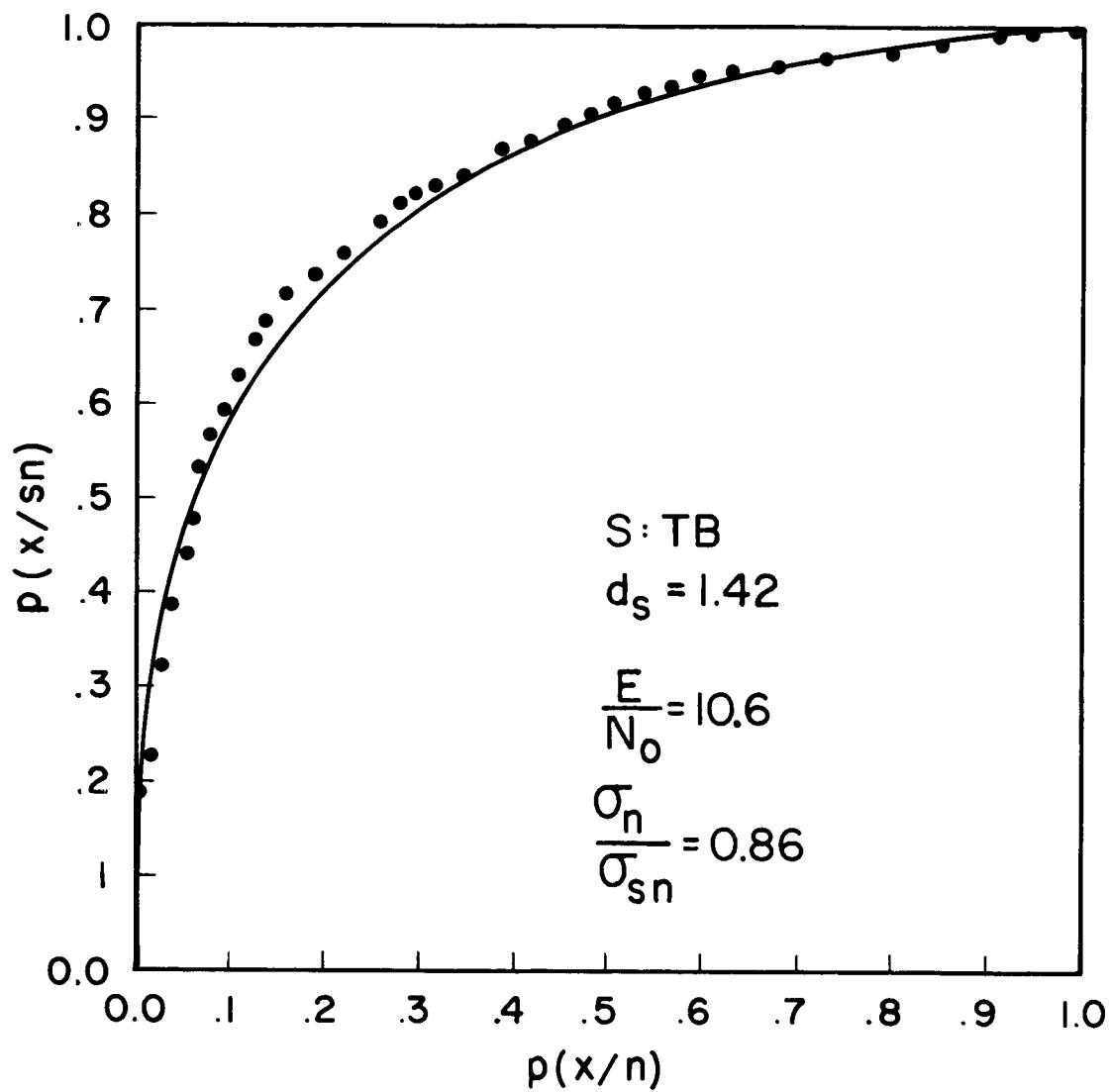
The scale was arbitrarily divided into 36 positions for recording purposes. The frequencies of responses in each division, to noise alone and to signal plus noise, were treated exactly as Egan (1959) had treated his discrete rating categories. The data were cumulated, so that each point of the ROC curve represented the probabilities, conditional on signal plus noise and on noise alone, of responding at a particular scale position or at one farther to the right. The resulting 36-point ROC curves were plotted and are shown in Dwgs. AS-8460, AS-8455, and AS-8457.

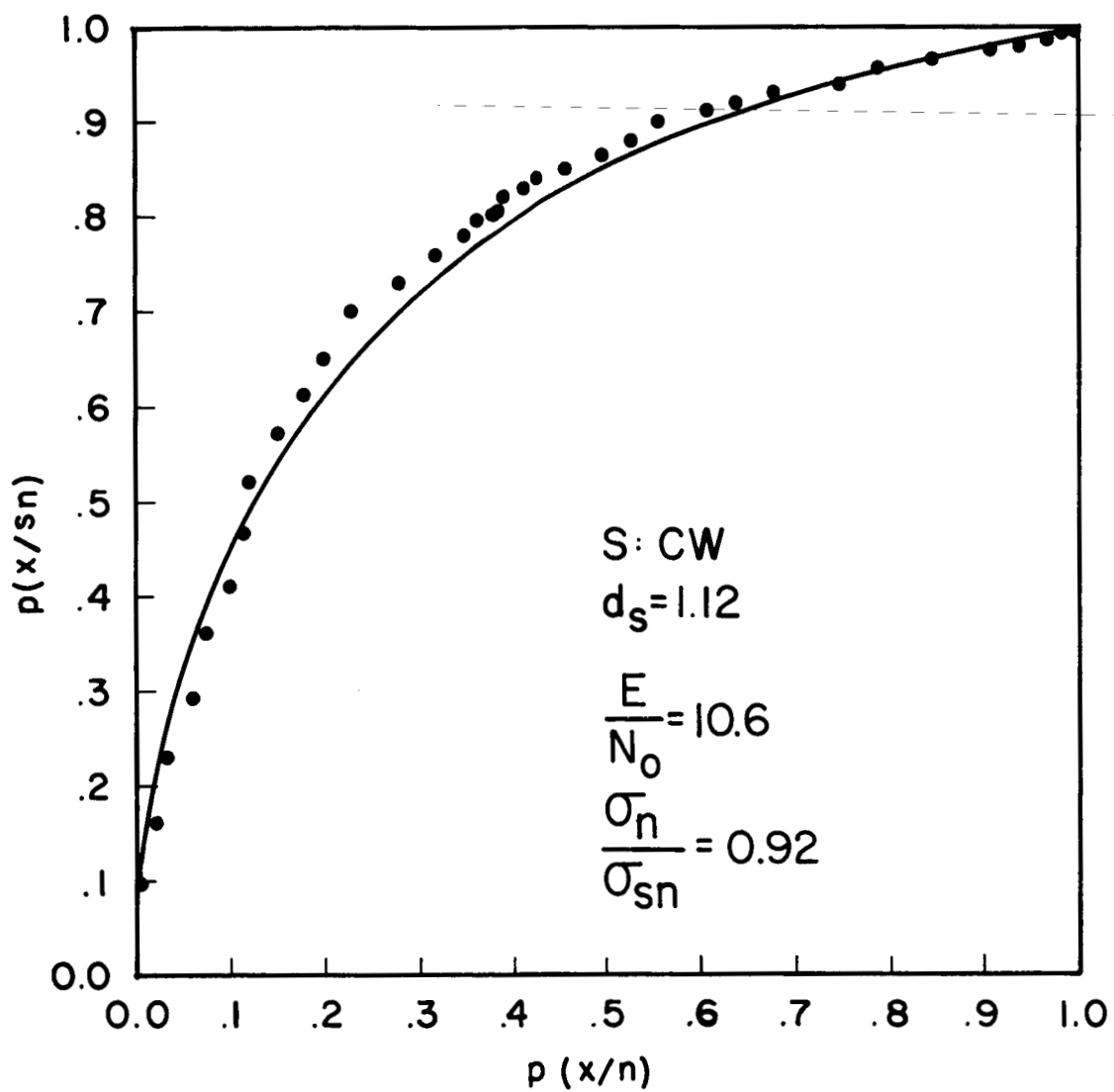
One result of the first study, which may be seen in Dwgs. AS-8460, AS-8455, and AS-8457, is that normal-normal ROC curves fit the data rather well; better, in fact, than other models that we knew about. This had also been the case with the data of Egan, Greenberg, and Schulman (1961). However, an orderly discrepancy was noticed...the data points overshoot the theoretical function in the center and fall below it in the tails. L. A. Jeffress (1964) has since shown that Rayleigh distributions would fit better than normal ones.

The next question was whether the technique is really sensitive to differences in physical input distributions or to cases in which the effective stimulus is different. L. A. Jeffress suggested that we try an antiphase case, masking with noise "in phase" at the two ears and the signal 180 degrees out of phase. It is known that subjects are 10 to 12 dB more efficient under this condition, and it has long been suspected that they are detecting time shifts rather than level changes under it...perhaps the ROC curves would have different shapes as well. The next study was an attempt to investigate the sensitivity of the rating-scale-analog procedure to this variation in stimulus configuration.

The noise and signal were essentially the same as in the earlier study: band limited noise from 100 to 3000 cps with the level per cycle 49 dB SPL and a 5000 cps signal, 150 milliseconds in duration, however, the signal level was reduced from 66.5 dB in the homophase study to 54.5 for the antiphase one. Receiver operating characteristics were plotted from the antiphase experiment using the same procedure as we had used earlier in the homophase experiment.





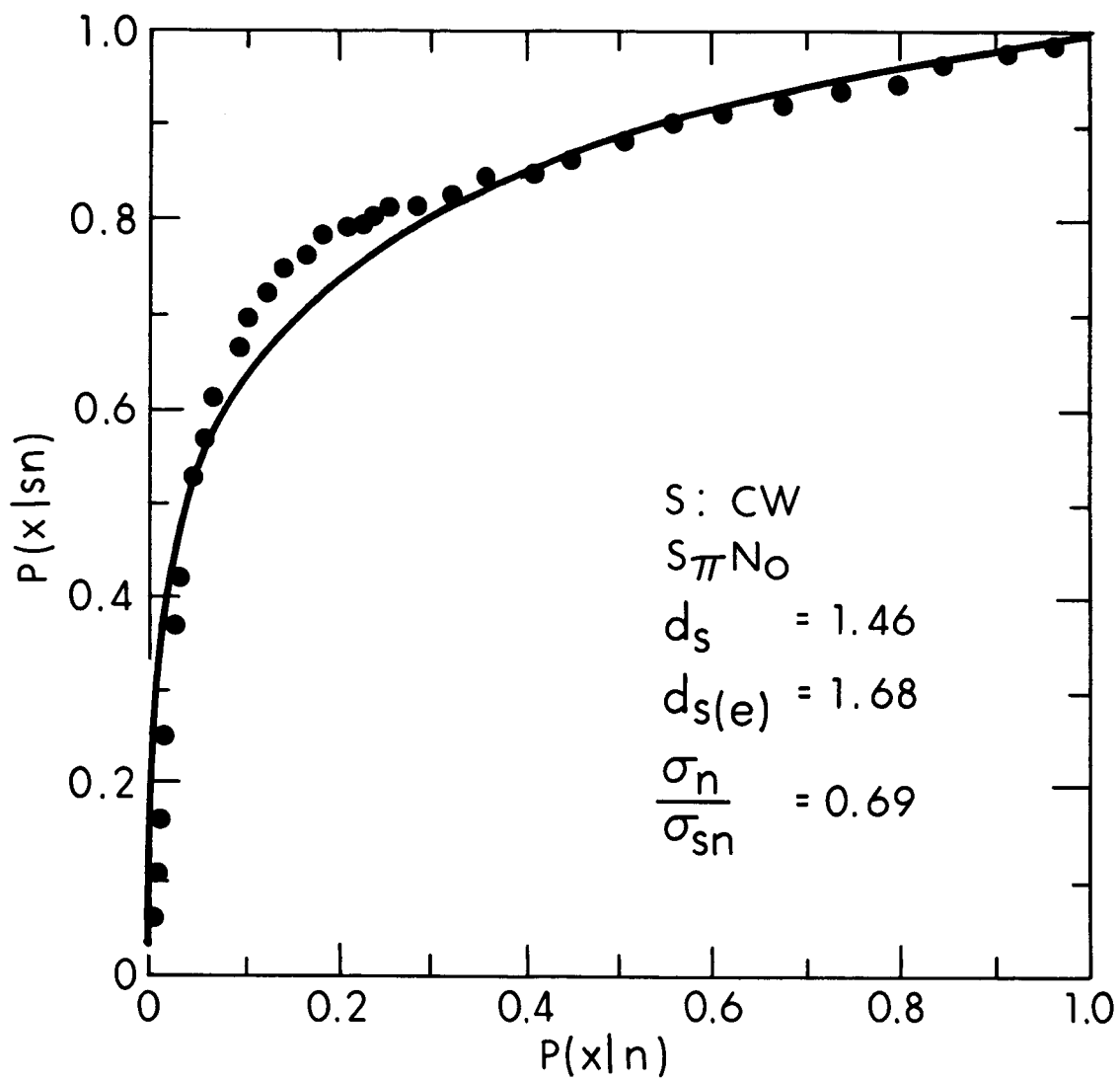


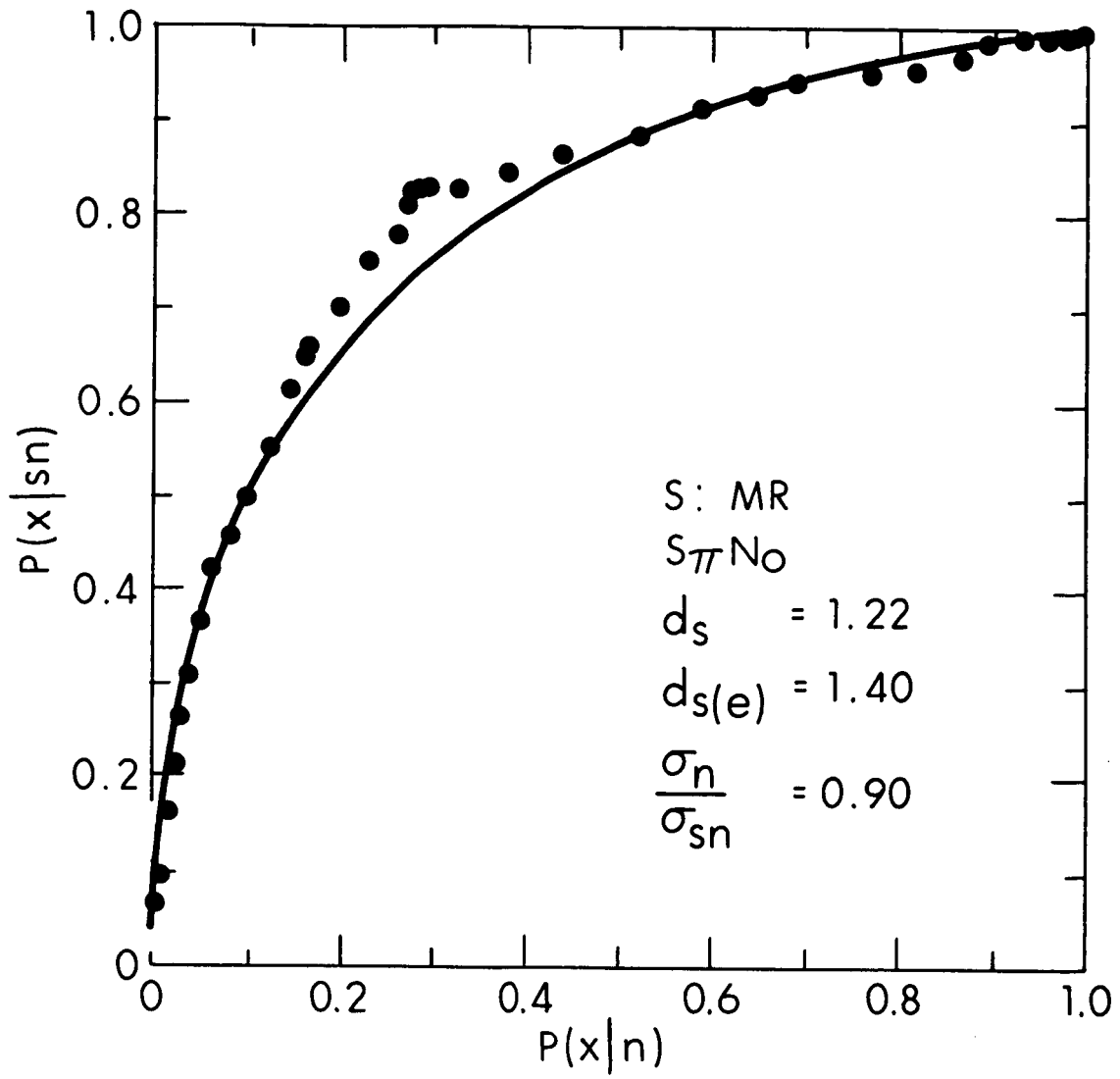
These curves are shown in Dwgs. AS-10082, AS-10081, and AS-10083. Two detectability indices, labeled  $d_s$  and  $d_{s(e)}$  were determined for each ROC, also as in the previous study. These values will be discussed later.

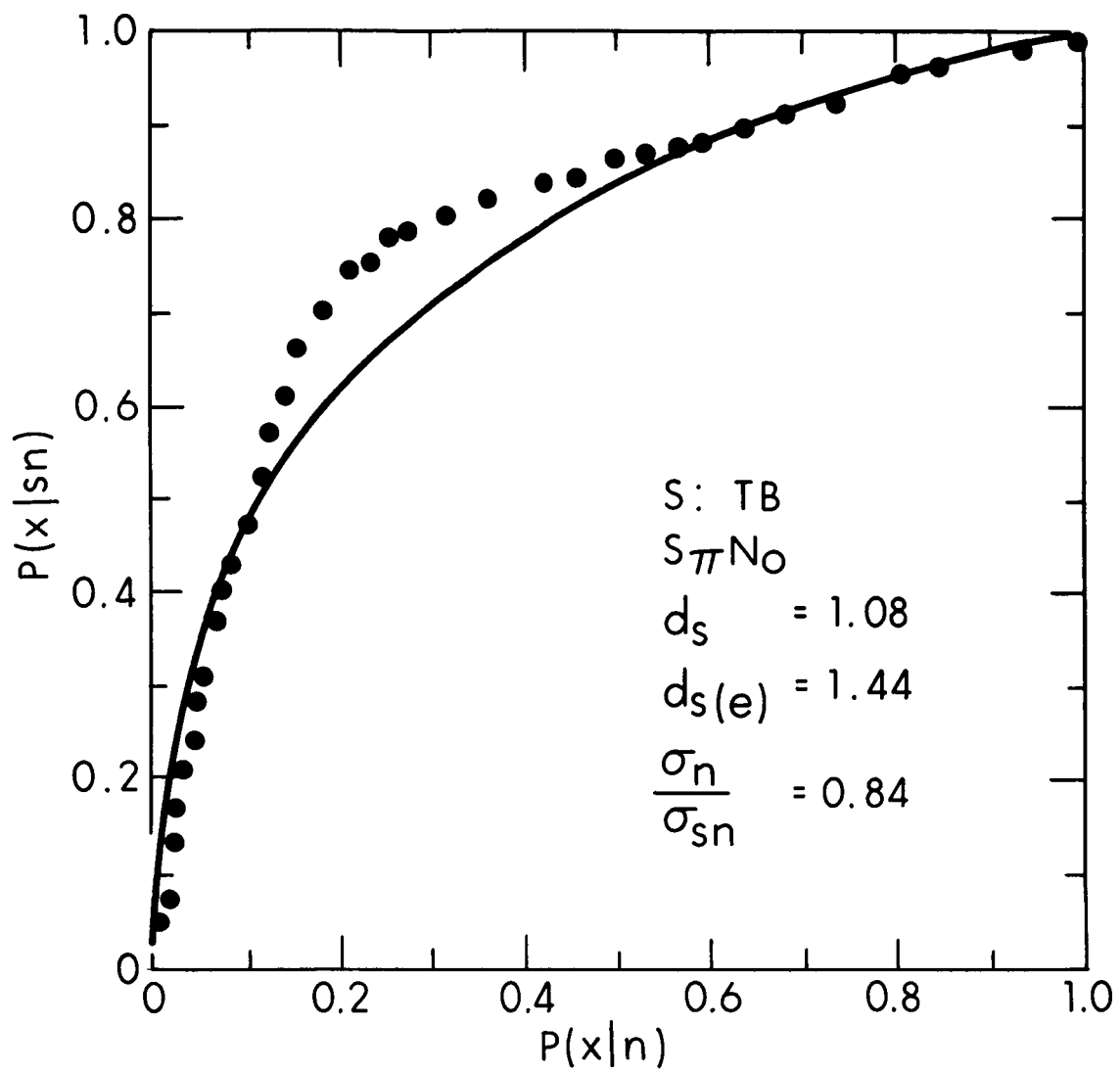
The shapes of the antiphasic ROC's are not predicted either by the normal-normal model nor by Rayleigh distributions. They deviate farther from either of these models in the vicinity of the negative diagonal than did the homophasic ROC curves. Two possible theoretical approaches might account for these functions. One is the two-straight-line threshold model proposed by Luce (1963). Straight lines do fit these data better than they did the homophasic ones, but the fits are still far from perfect when the constraint is applied that one line segment must pass through the origin and the other through the point 1.0, 1.0. (The authors suggest that the reader attempt to fit straight lines to these functions.) A second theoretical basis for these functions has been proposed by Jeffress and will be presented in detail elsewhere...Jeffress's model involves temporal- rather than level-related neural noise. By assuming this noise to be normally distributed he is able to fit some of these data quite effectively. At the present time the authors believe the neural-noise based theory more consistent with other established facts than the threshold theory.

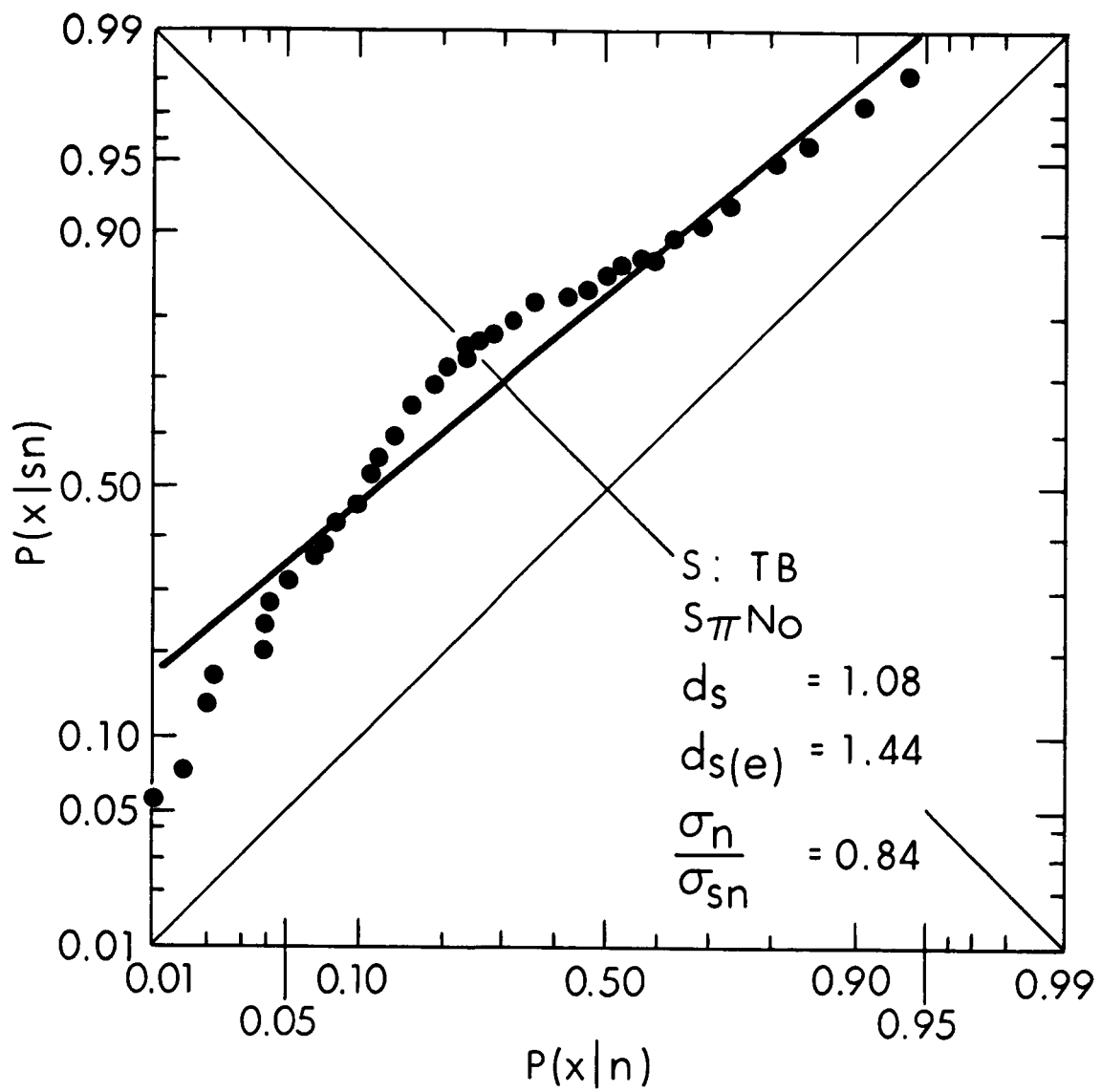
The abnormality of these functions is shown even more clearly in Dwg. AS-10085, where the data for one subject is plotted on a normal-normal coordinate system. The straight line is a rough and ready fit. We hesitated to measure a detection index from the intersection of this line with the negative diagonal, but the intersection of the real points with the diagonal seemed to lead to spurious conclusions as well. This is illustrated graphically in Dwg. AS-10084.

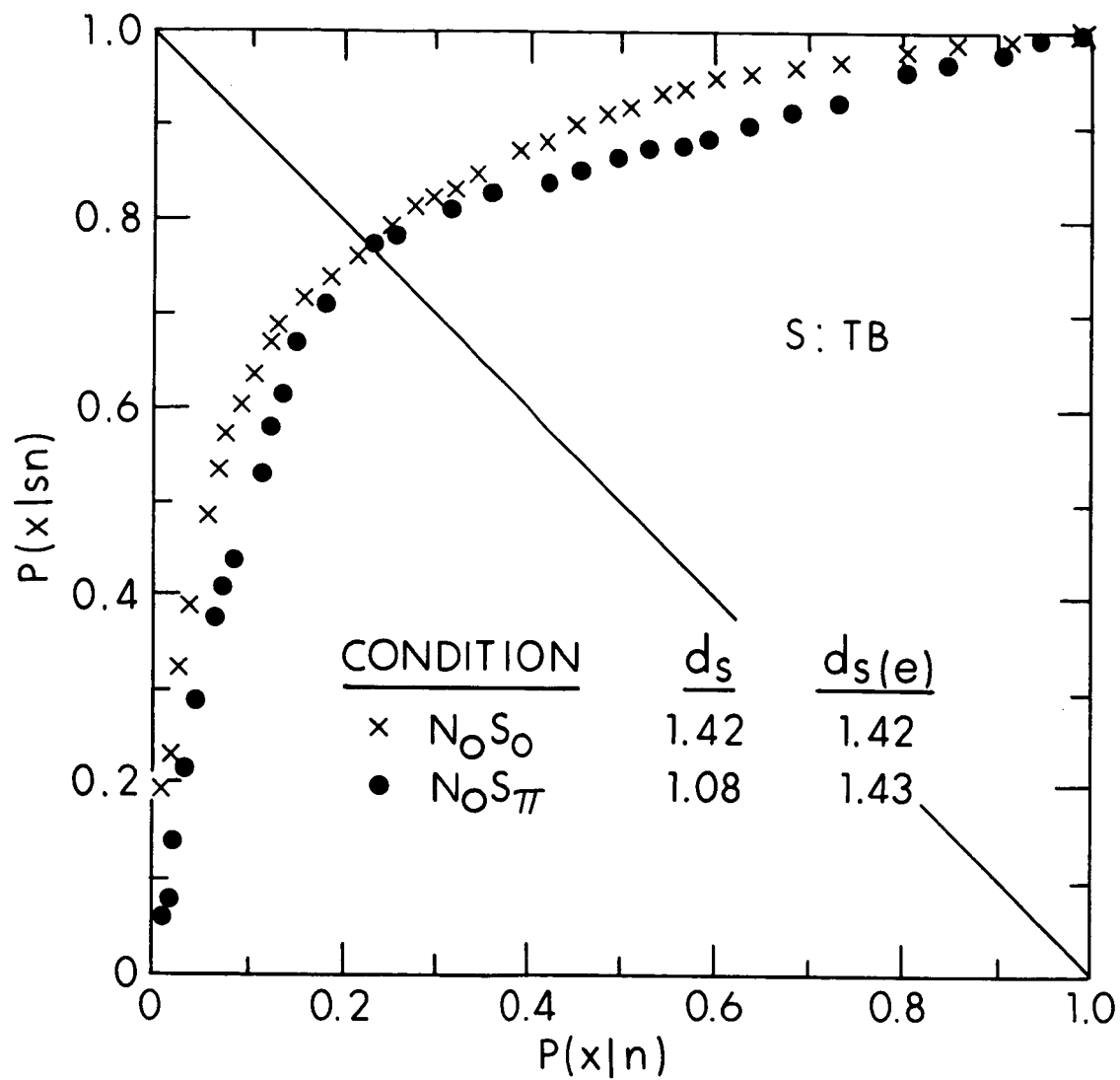
In Dwg. AS-10084, the X's are the ROC curve from the homophasic condition, the solid circles, those from the antiphasic one, for the same subject. By chance, for this subject the two curves intersect the negative diagonal in about the same place. Values of the detectability index,  $d_s$ , shown on this drawing and in the earlier ones, were determined using the definition proposed by Egan, et al (1961). This is the value of  $d'$  for the normal, equal-variance ROC which best fits the data on a normal coordinate system. A more empirical index, labeled  $d_{s(e)}$ , was also defined. It is the  $d'$  for a normal, equal-variance ROC which intersects the negative diagonal in the same place as the observed ROC. These two definitions will yield identical values for ROC's generated by normal distributions, no matter what the ratio of  $\sigma_{SN}/\sigma_N$ .











That  $d_s$  and  $d_{s(e)}$  are widely separated for these ROC's is strong evidence against using normal-distribution-based statistics to describe them. The functions in Dwg. AS-10084 are clearly different in that the antiphasic ROC falls below the homophasic one throughout most of its range. This is reflected in the difference between the two values of  $d_s$ . These functions have the same value at the negative diagonal, and this similarity is shown in the values of  $d_{s(e)}$ . Neither index alone is an adequate representation of the detectability relationship between these two conditions.

Green (1964) has shown that one way around the problem of the shape of the ROC curve is to ignore it, that is, to use distribution-free forced choice procedures rather than the single interval method. In the two-alternative, forced choice procedure, Green shows that the percent correct,  $p(c)$ , is equal to the area under the ROC curve that would be obtained for the same stimulus conditions, with a single interval experiment. Working backwards, we used a planimeter to measure the areas under these ROC's and found them to be 84.5 and 79.8 percent, respectively, of the total space. The associated values of  $d'$  are 1.44 and 1.19. These values are probably more useful than either of the  $d_s$ 's. However, for a single criterion value, observers can do equally well in a single interval experiment for either condition.

Egan (1958) suggested that one measure of detectability for the single interval experiment might be the maximum percent correct, defined as the maximum sum of hits plus correct rejections. This measure is represented by the single point on the operating characteristic where the slope of this function is 1.0 and the distance to the chance line is at a maximum. Operating characteristics that were symmetrical about the negative diagonal would have such a point on the negative diagonal, and for these cases the measure would be no more useful than  $d'$ . But for all asymmetrical ROC curves, a better pair of measures might be maximum percent correct and the criterion that must be adopted to achieve this maximum. Thus, for the two ROC curves in Dwg. AS-10084, maximum percent correct is 79 and the criterion ( $\beta$ ) required for this maximum is approximately 1.0, where  $\beta$  is the optimum value of the likelihood ratio,  $\lambda(x) = f(x/x_n)/f(x/n)$ , as defined by Swets, Tanner, and Birdsall (1961).

Thus, to deal adequately with the single interval case, it is essential to know the shape of the ROC curve. We now believe that, when dealing with a new detection situation, the first order of business should be to determine the shape of this function. The analog rating procedures is one way to do this.

## References

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## APPENDIX C

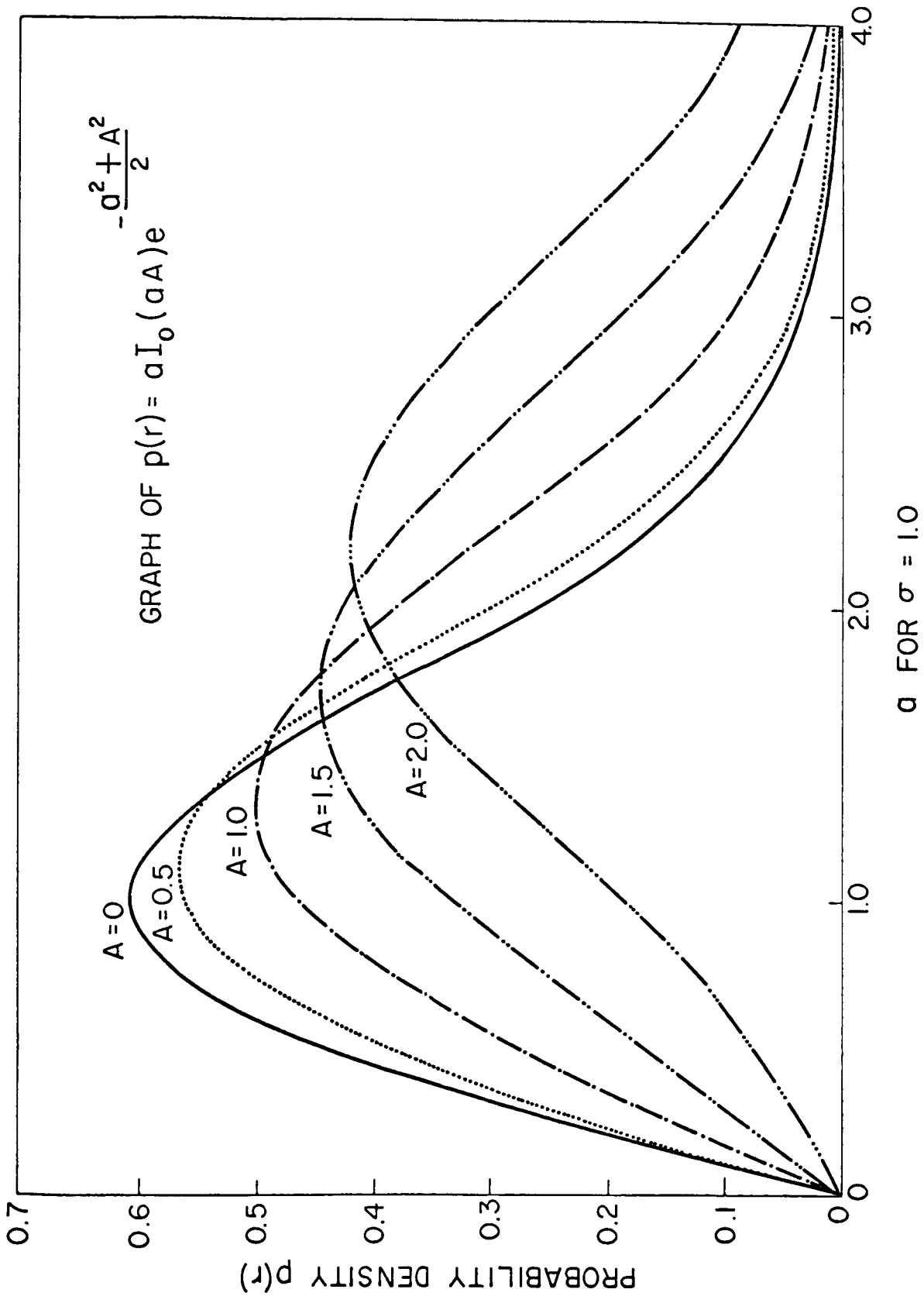
### Theoretical and Obtained ROC Curves for Antiphasic Stimulation

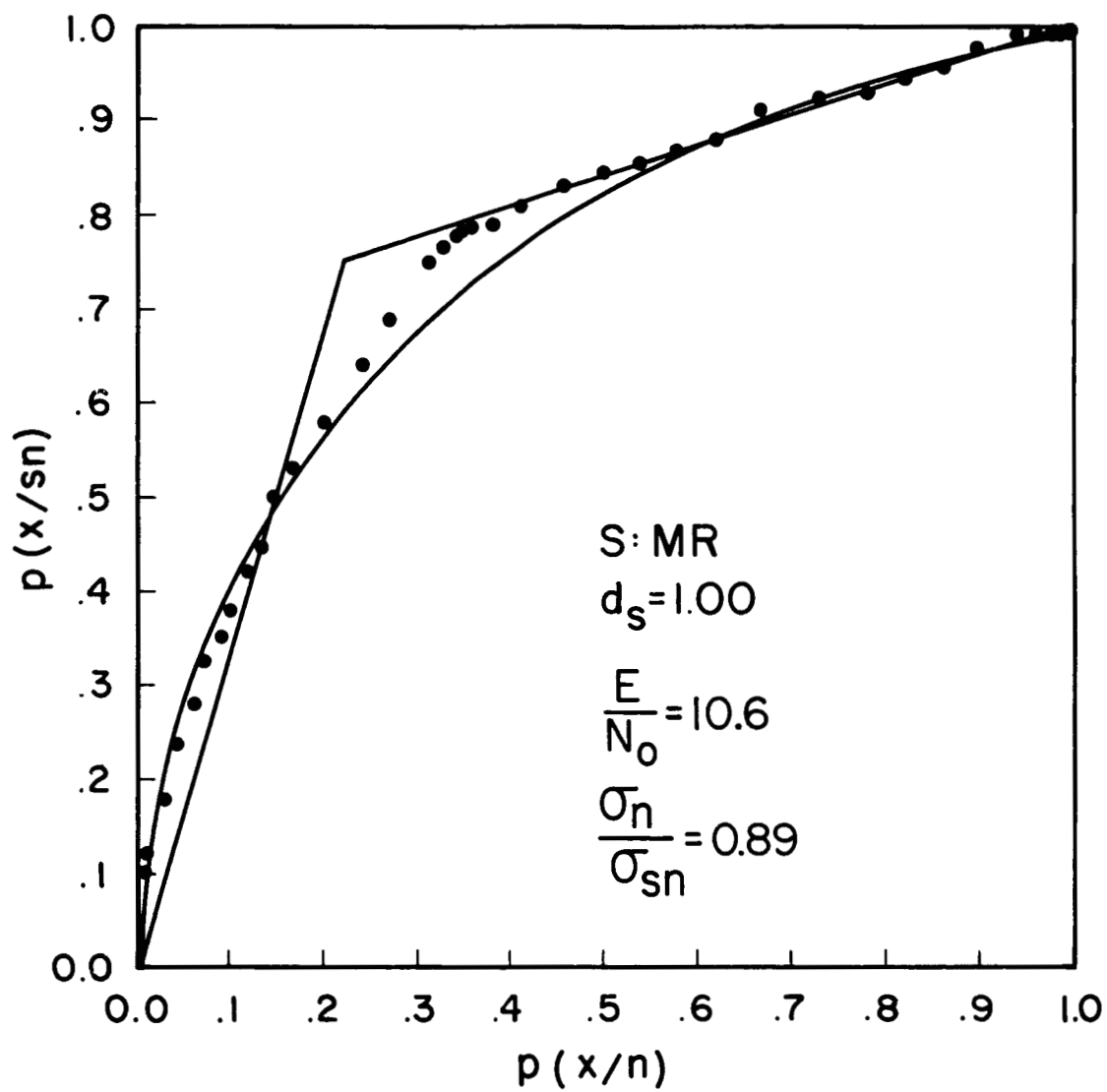
Lloyd A. Jeffress, Charles S. Watson, Mark E. Rilling, and Walter T. Bourbon

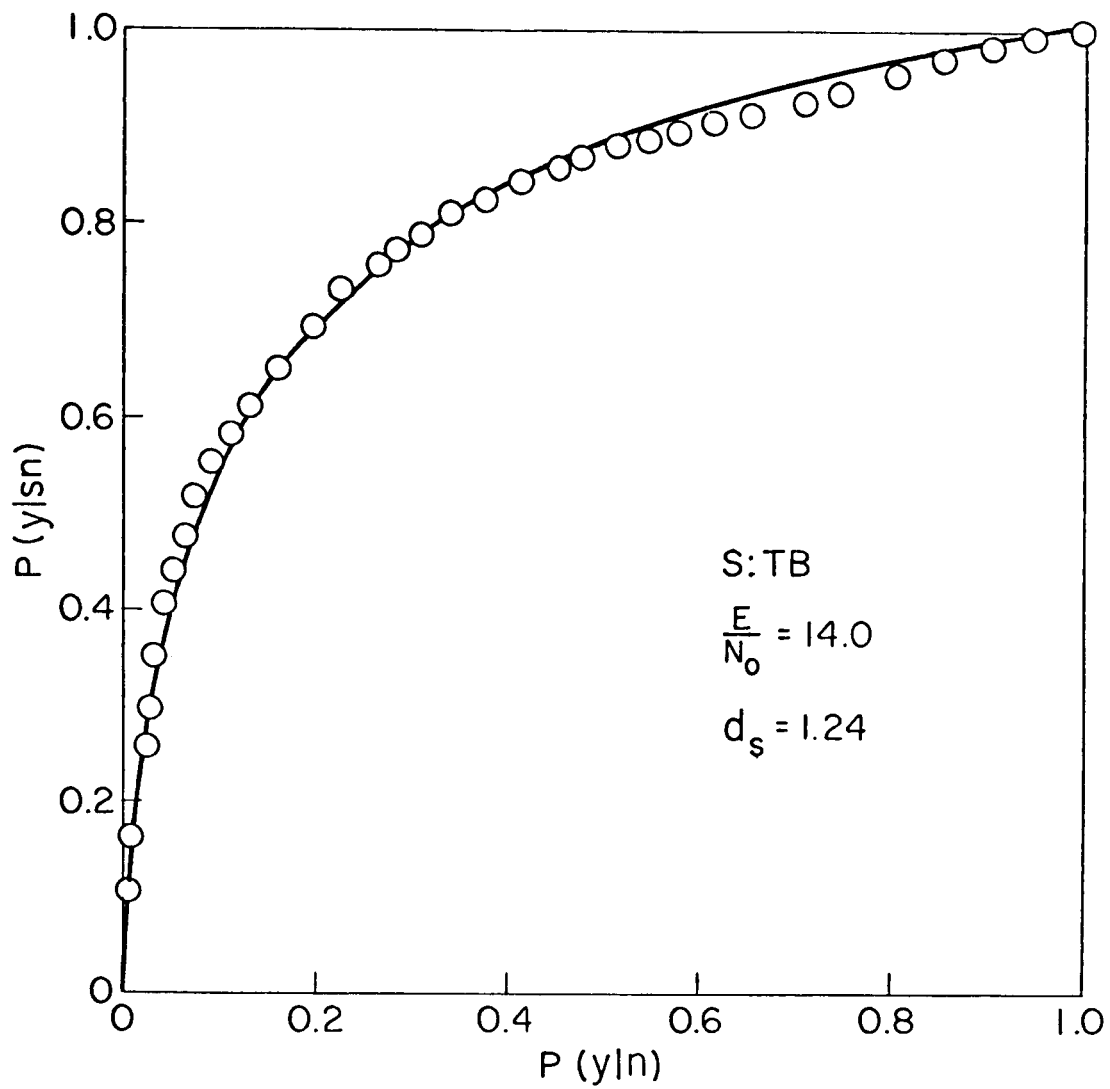
This paper is partly a plug for the rating-scale technique described in the last paper, and partly a venture into some further theory. Instead of assuming that the noise and signal-plus-noise distributions for the monaural or the homophasic detection are normal, let us assume that they have the form given in Dwg. AS-8602. These, as Peterson, Birdsall, and Fox showed are the functions for the ideal detector for the case where signal phase is not known. They are also the distribution functions for the amplitude or envelope of narrow-band noise and noise plus signal. If we use them instead of normal distributions to develop an ROC curve, we obtain the fit for the data of the second drawing of the previous paper (Dwg. AS-8460) shown in Dwg. AS-8603.

Now let us consider the data for the remaining drawings of the previous paper. The noise is in phase at the two ears but the signal is reversed in phase. For this antiphasic condition the signal required for detection is some ten or twelve decibels below what is required for equal detection under the homophasic or the monaural condition. The mechanism is obviously quite different. We have every reason to believe that the effective stimulus is now the interaural time difference that is introduced when an antiphasic signal is added to a diotic noise. For a given noise level and bandwidth, and for a given signal level, we can compute the expected values of the resulting time differences. Before doing so let us consider the nature of the noise distribution with which we are now concerned.

If we were dealing throughout with perfect transducers and perfect transmission, there would be no noise. Each rarefaction peak of the 500 cps narrow band of noise would send a nerve impulse centrally, and those from the two sides would be simultaneous. They would provide a reference plane of infinitesimal thickness, from which any departure, such as that caused by adding an antiphasic signal would be conspicuous. The effective signal-to-noise ratio would be infinite for any signal. But neither the ears nor the neural transmission is perfect. Firing does not occur at precisely the same part of the cycle each time or at each ear. There will be slope, and our median plane will have thickness, or fuzziness.







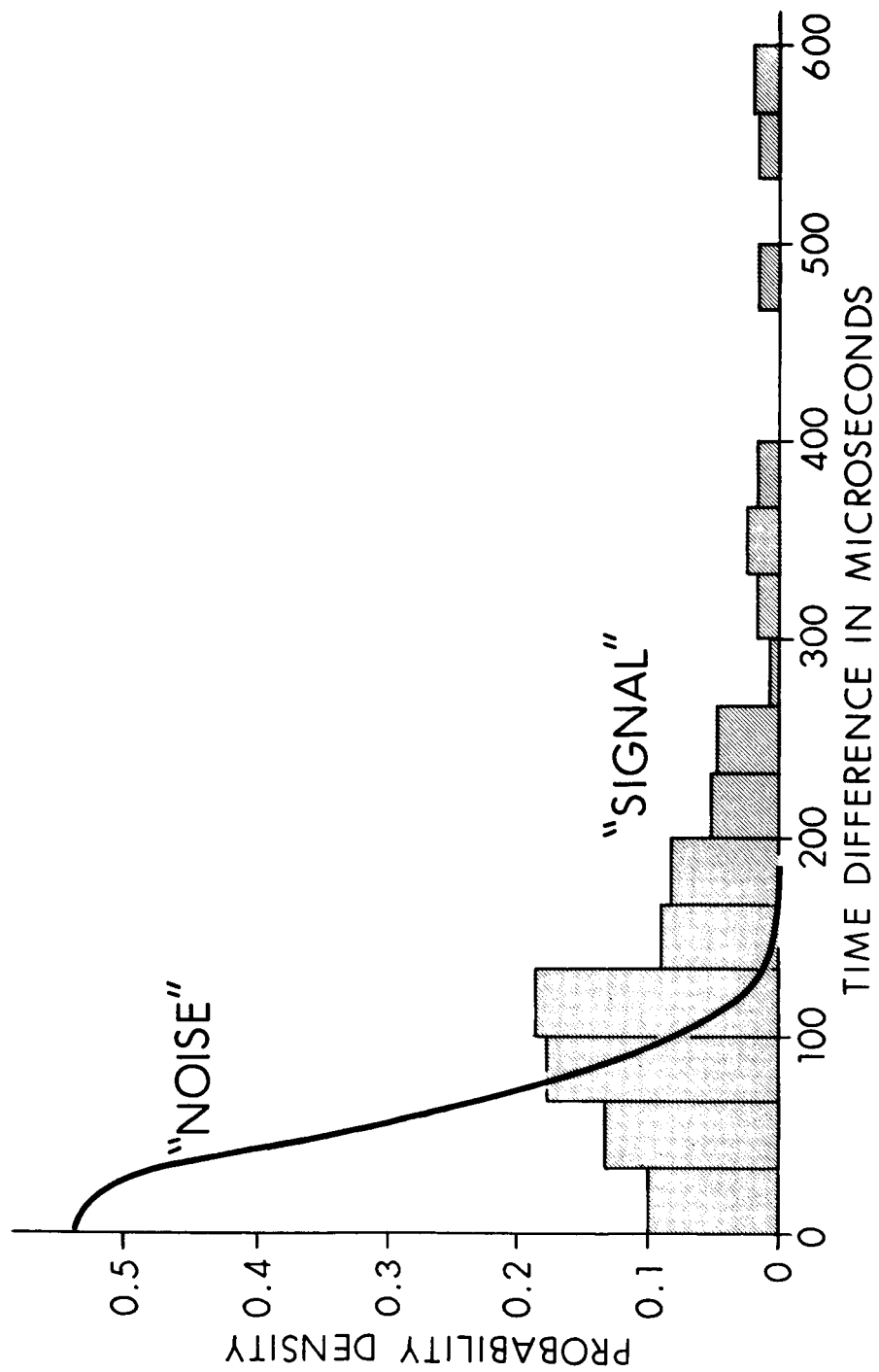
It is the departure of the signal plus noise from the median plane that constitutes the effective signal, and the thickness or fuzziness of the plane constitutes the noise. We can compute the distribution function for the signal, but what about the noise? Since the firing irregularities are a concatenation of a large number of presumably random factors, a reasonable assumption appears to be that the noise distribution is normal and is symmetrical about the median plane. The signal distribution is also symmetrical about the median plane. But since the subject in the rating-scale experiment is responding to the magnitude of the stimulus, and not to its direction, we will be concerned with only one-half of each distribution.

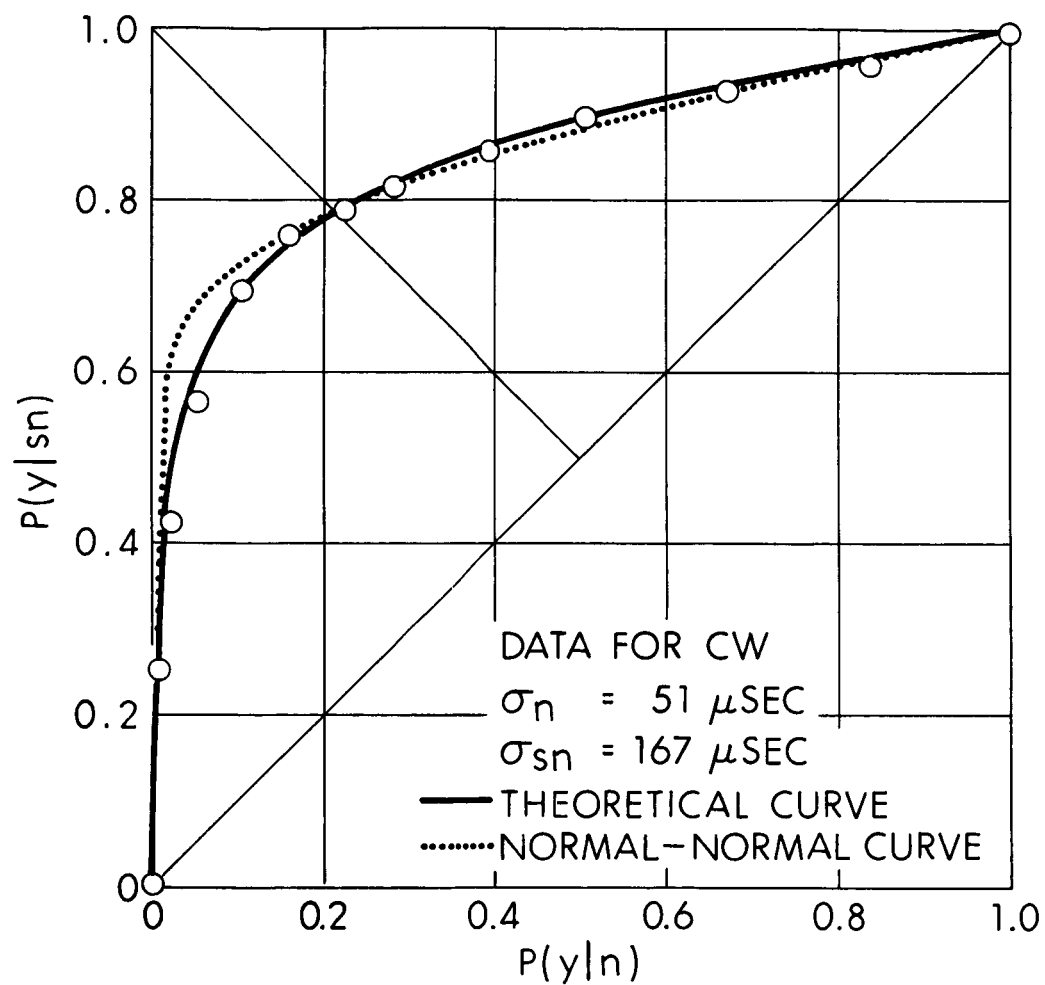
Drawing AS-10067 shows the two distributions. The noise distribution is half of a normal curve. The signal distribution was obtained by solving 120 pairs of vector triangles, derived by taking ten, mid-decile values of the noise amplitude, and twelve phase angles at  $15^\circ$  steps. The interaural phase angle for each combination was determined and converted to time difference for the signal frequency 500 cps. The magnitudes of the noise, and signal amplitude were those employed in the previous experiment. We are left with one adjustable parameter, the ratio of the standard deviations for noise and signal. This was chosen to fit one data point, that at the negative diagonal. The resulting ROC curve for one of the subjects of the previous paper, is shown in Dwg. AS-10068. As can be seen, the fit is reasonably good. The dashed line is the ROC curve derived from two normal distributions with the ratio of standard deviations chosen to fit at the negative diagonal. It will be seen that this curve predicts too few false alarms in the high-criterion region--lower left.

I should mention that the data for the other two subjects were not so well fitted. Only by assuming that the noise distribution was somewhat platykurtic could a good fit be obtained.

Our next venture is to develop a theoretical family of ROC curves for this stimulus condition. It is waiting on a computer program for doing the necessary trigonometry.

The moral of the last two papers appears to be that shape of the ROC curve can tell you a great deal more about the nature of the stimulus than can be learned from any single detection measure. The rating-scale gadget is proving to be a real boon to psychophysics.





ROC CURVE FOR NO  $S\pi$  CONDITION

## APPENDIX D

### Auditory Sensitization and the Method of Interpolated Trials

Charles S. Watson and Ben M. Clopton

It is usually assumed that the well-trained listener has fairly stable auditory sensitivity over time. Studies of the effects of practice, motivation, and feedback on observer performance include Swets and Sewall (1963), Blackwell (1953), Lukaszewski and Elliot (1962), Zwislocki, Maire, Feldman, and Rubin (1958). These studies indicate that, with well-trained observers and optimum conditions of signal specification and feedback, the effects of motivational factors are practically negligible over the usual testing periods.

Two recent developments bear upon motivational effects in the detection situation. One is the Theory of Signal Detectability (TSD) which suggests that response changes, once thought to be motivationally-induced, are often changes in the acceptance criterion of the observer (Swets, 1961; Swets, Tanner, and Birdsall, 1961). The other development is strong neurophysiological evidence that most receptors have efferent fibers leading to them as well as afferents leaving them. Considerable support exists for the idea that these efferents can modify receptor sensitivity, in terms of gross neural responses, as a function of the organism's attentiveness to the stimulus. (Granit, 1955; Galambos, 1956; Hagbarth and Kerr, 1954; Hernández-Peón, 1961). The first development suggests relative stability in observer performance across levels of attention or motivation, but the second suggests possible short-term variations due to neural processes.

The apparent contradiction is resolved when the respective time periods are considered. TSD investigations have normally measured average sensitivity over a minimum of five-minute sessions, and more often, over blocks of sessions, or even days. These investigations seem to describe long-term observer sensitivity rather well, but they are not suited to detect transient sensitivity changes in the order of seconds. While the evidence does not rule out long-term motivational effects, changes in the pattern of neural responses have generally been found to be quite short. Hernández-Peón finds that, in his work, causing an animal to attend to a stimulus typically leads to a rapid elevation of the neural response lasting only 10 to 20 seconds, an effect which is similar to that obtained by electrical stimulation of the brain-stem reticular formation.

The above considerations led us to develop what we call the Method of Interpolated Trials (MIT) to investigate possible short-term effects. The procedure requires inserting "special" trials into a trial sequence and observing the related responses. Before starting on the interpolated-trial sequence, one should push the performance of observers up as far as possible to assure comparison of enhanced sensitivity with a meaningful standard. To make the "special" trials special, it is necessary to associate reward or punishment with correct or incorrect responses on these trials. Also, while increments in sensitivity on interpolated trials may be anticipated, one should look at responses on trials following the interpolated ones to see if the increment is of a prolonged duration.

Each of our studies has been on the masking of a 500 cps tone (150-msec duration, 25-msec rise-decay) by a 100-3000 cps band of noise. The level of the tone was 66.5 dB. SPL and the level per cycle of the noise was 49 dB. The basic psychophysical procedure was two-alternative-forced-choice, where a trial consisted of two lights flashed in sequence, each 175-msec in duration, one of which included the signal by random schedule. The inter-light interval was 500 msec, and the trials were presented once every three seconds.

#### Experiment 1

In a preliminary experiment we told the observer that occasionally a large (five-inch square) light would come on prior to a trial to signify that it was a "crucial one." No significant change in detection was observed, i.e., telling the observer that these trials were important didn't seem to make them so.

#### Experiment 2

In a later experiment we gave a 1.6 milliamp shock across one ankle for incorrect responses on interpolated trials. The shock was first used with three listeners previously trained for 14 daily sessions in the masking situation. These listeners were then instructed on the interpolated-trials procedure and run under it for six days. Six blocks of 120 trials each were run per day. In the MIT, 12 of the trials in each block were randomly selected as interpolated trials, and the subjects were shocked on them for incorrect responses. They were shocked, on the average, only two or three times per block, and we found no sign of the shock becoming less noxious over time. Six sets of counters were used to separately record the responses on the interpolated trials, the four trials after an interpolated trial, and the responses on all other "normal" trials.

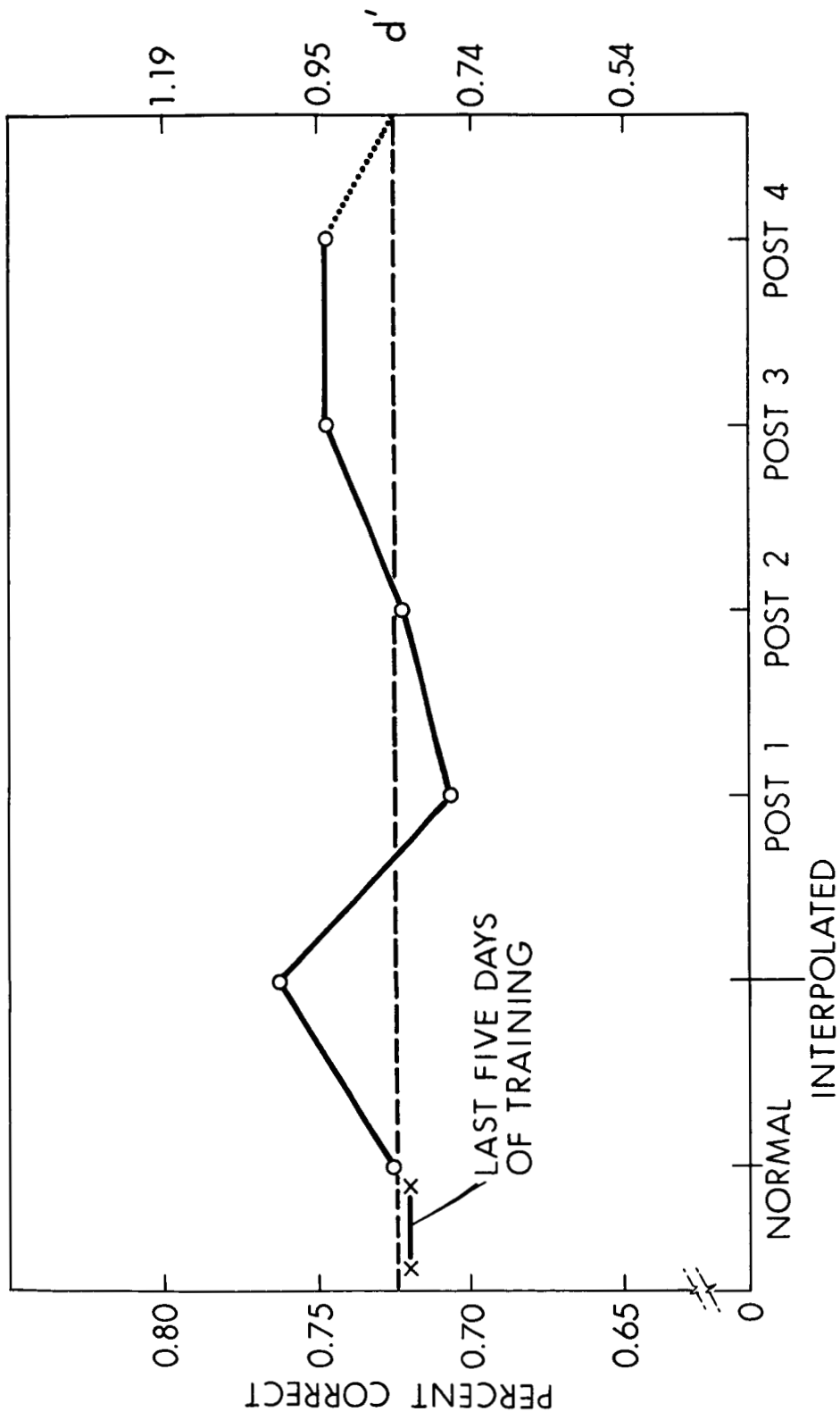
Drawing AS-10086 shows the three-observer, averaged results. Performances over the last five days of training and over normal trials in MIT are almost identical at 72 percent correct. Performance increased to 76 percent correct on interpolated trials (not quite equivalent to a 2-dB signal increment) and fell to 70 percent on the first post-interpolated trial. The depression on post 1 and 2 and the swing above normal on post 3 and 4 suggests that the observers might have been paying more attention to their ankles than the task, and that the course of heightened sensitivity might be longer than could be measured with single interpolated trials. The data points represent 1300 responses for each interpolated and post-interpolated trial and 6400 for normal trials.

### Experiment 3

The procedure for the next experiment was the same except that a sequence of four interpolated trials was used instead of only one, six sets of four to a block of 12<sup>4</sup> trials. Four observers were used. Drawing AS-10088 shows the individual results and Dwg. AS-10087 the averaged results. The dashed lines of Dwg. AS-10087 are the levels of performance during 16 days of training, and show improvement as we added various standard forms of motivation. The first improvement (line 2) resulted from a "between-the-halves talk," and the second (line 3) from feedback at the end of each 12<sup>4</sup>-trial block. The maximum reached during the interpolated trials was greater than that achieved with the best of the other procedures. It was equivalent to better than a 2-dB increment in signal level over the normal trials (line 4). It is significant that the maximum improvement did not occur until the second interpolated trial, and that a decrease from this maximum is seen on the last two interpolated trials. The decrease could have been due to interference caused by shock on some of the preceding interpolated trials. The next study attempted to investigate such possible interference.

### Experiment 4

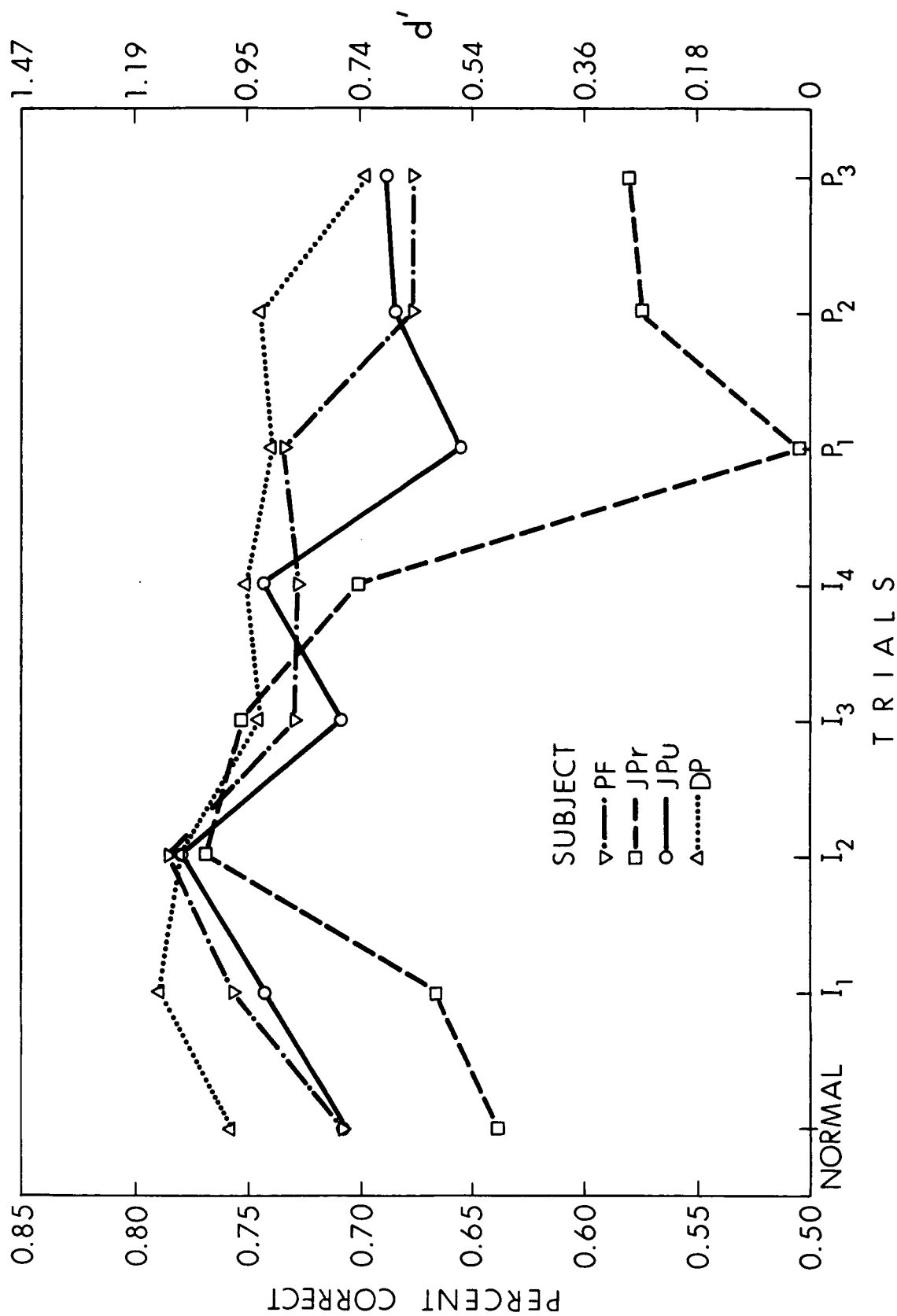
The observer could expect one, two, or three interpolated trials in sequence in the following study. The possibility of shock was present only on the last interpolated trial of a sequence so that every interpolated trial presented equal apriori threat since the sequence was chosen randomly. Also, the occurrence of a trial was reduced from once every three seconds to once every 2.85 seconds. Drawing AS-10089 shows the data from two observers. Without possible interference from shock in immediately-preceding interpolated trials, improvement in performance



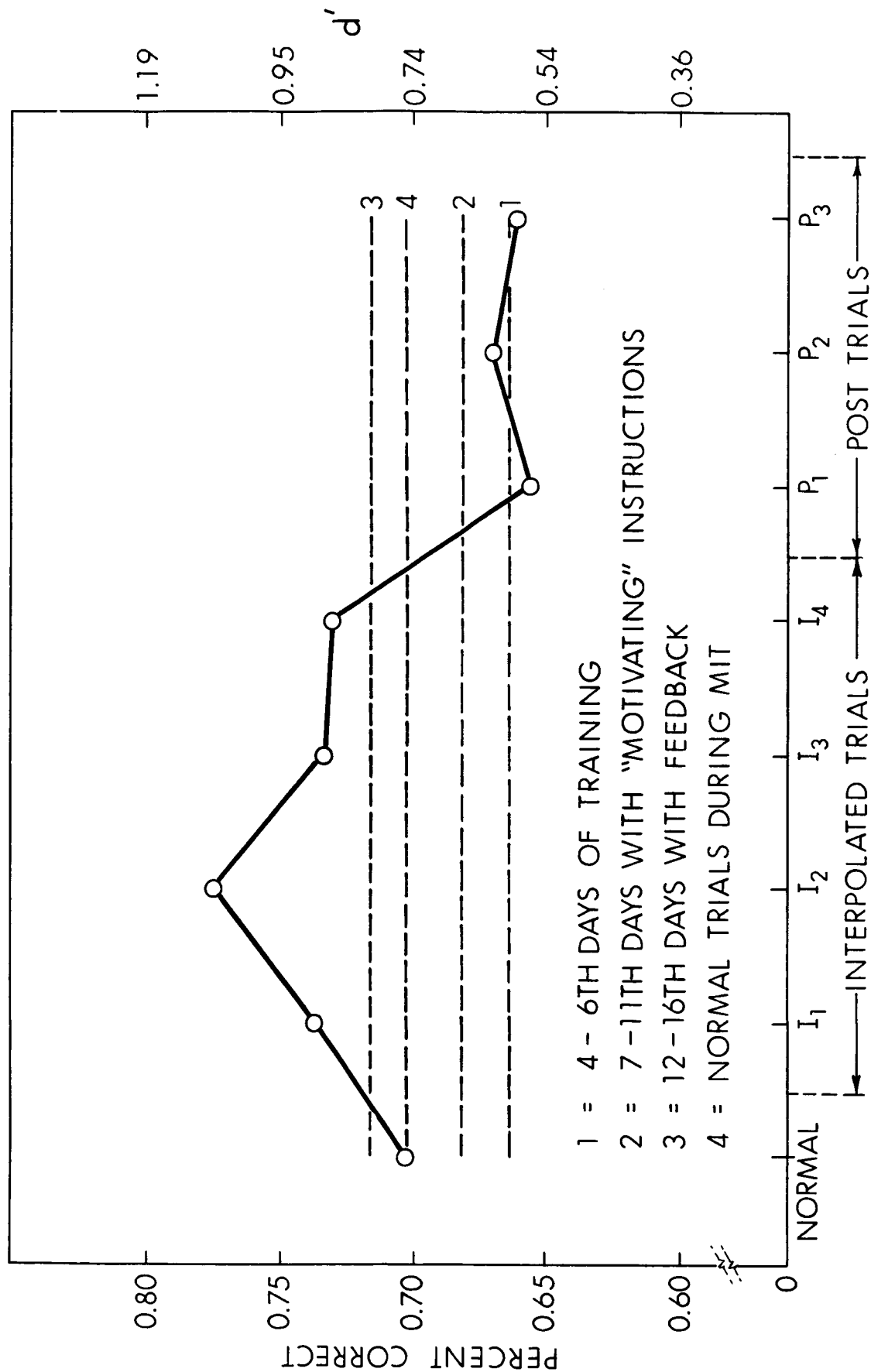
T R I A L S

## METHOD OF INTERPOLATED TRIALS, EXP 2

### AVERAGE OF 3 $\bar{S}_s$ 2IFC, SINGLE INTERPOLATED TRIALS

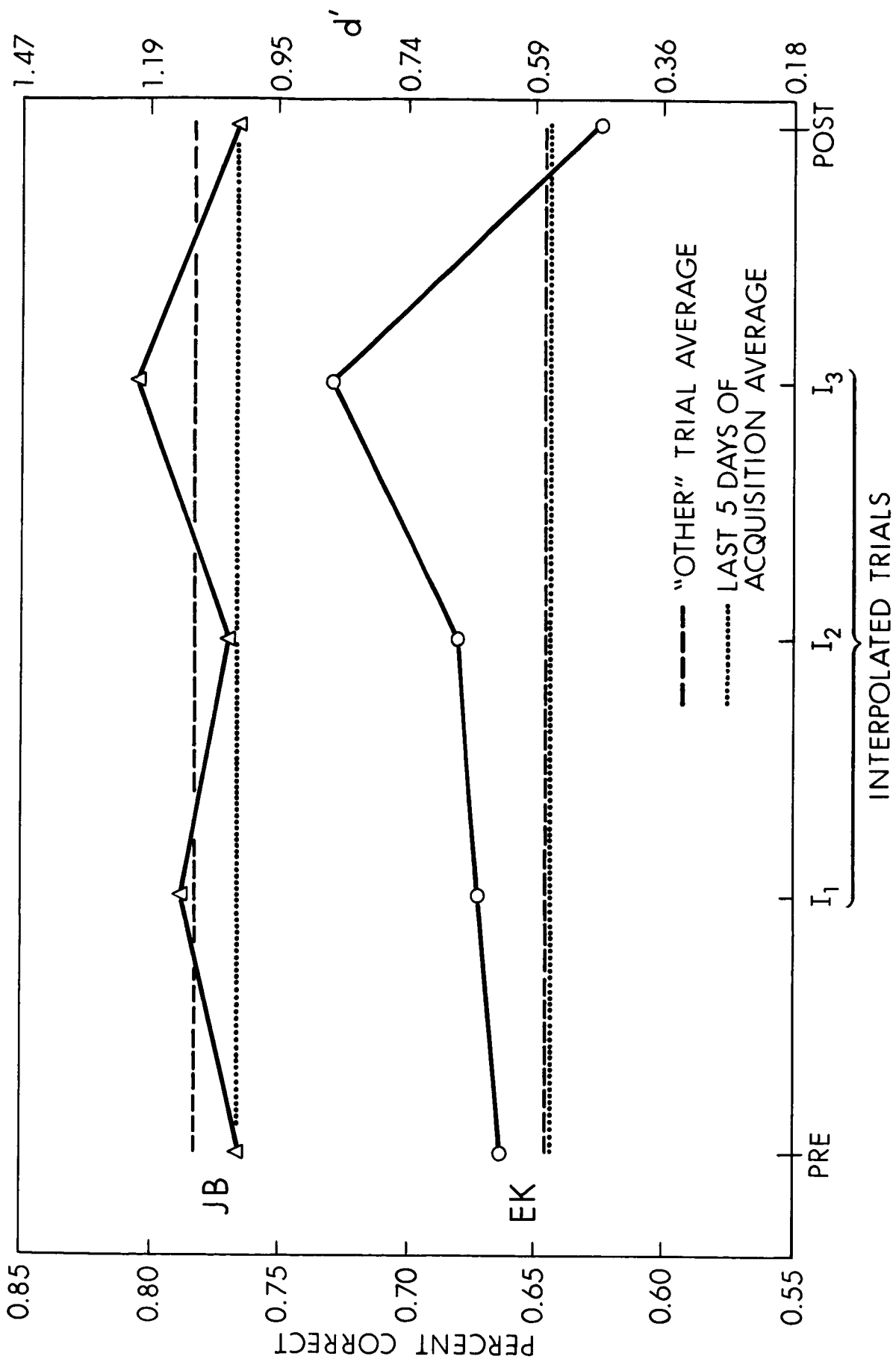


# METHOD OF INTERPOLATED TRIALS, EXP 3



- 1 = 4 - 6TH DAYS OF TRAINING
- 2 = 7 - 11TH DAYS WITH "MOTIVATING" INSTRUCTIONS
- 3 = 12 - 16TH DAYS WITH FEEDBACK
- 4 = NORMAL TRIALS DURING MIT

## METHOD OF INTERPOLATED TRIALS, EXP 3



# METHOD OF INTERPOLATED TRIALS, EXP 4

continues to the third interpolated trial, i.e., for a period of over seven seconds from the onset of the first interpolated trial of a sequence. As in Dwg. AS-10088, the observers with lower initial performance show greater improvement on interpolated trials.

The results of each of these experiments show enhanced sensitivity over that which could be produced by even the most rigorous standard psychophysical techniques. While each observer showed such increments when threatened with shock, the magnitude of the increment varied considerably between observers. Drawing AS-6528 shows these increments in performance as a function of average percent correct on normal trials. Clearly, the better the subjects are doing on normal trials the less the increment when they are threatened with shock. (Coefficient of correlation =  $-.85$ .) One interpretation of this result is that maximum possible performance for the human observer in this task is approximately 82 percent correct, given by extrapolating a line fitted to the points in Dwg. AS-6528 to its intersection with the abscissa. This is an interesting interpretation, since an empirical upper limit on human performance might offer more useful measures of individual observer's efficiency than is currently possible by comparing them to theoretical "ideal" detecting mechanisms.

The results of these experiments are:

1. The MIT produces increments in performance for the average observer which are comparable to those produced by about a 2 dB increase in the level of a sine-wave signal, or about 60 percent increase in signal energy.
2. These increments in sensitivity are produced on demand, that is, they can be produced at any moment in time selected by the experimenter.
3. The best current estimate of the time course of these effects is a gradual rise in sensitivity to a maximum requiring three to five seconds, and a decay of ten to fifteen seconds after this maximum has been reached. This time course may be in part a function of the effects of occasional punishment in the present experiments.
4. Observers with the poorest sensitivity on normal trials show the largest increments when threatened with shock, while the best observers show small increments. (The distribution of performance scores on normal trials was typical of highly trained experimental subjects.)
5. The inverse relation between normal performance and size of increments in performance on interpolated trials can be extrapolated to yield a more empirical and perhaps more useful upper limit for human observers than those currently proposed by theories of signal detectability.

13 January 1965

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